Breast Coil for Real Time MRI Guided Interventional Device

X. Zhai[1], K. Kurpad[1], M. Smith[2], D. Mahay[3], R. Harter[4], and S. Fain[1]

[1]Department of Medical Physics, University of Wisconsin, Madison, Wisconsin, United States, [2]Department of Biomedical Engineering, University of Wisconsin, Madison, Wisconsin, United States, [3]Department of Electrical and Computer Engineering, University of Wisconsin, Madison, Wisconsin, United States, [4]Marvel Medtech, LLC., Madison, Wisconsin, United States

Introduction:

Magnetic Resonance Imaging (MRI) provides visualization of breast lesions that escape detection with other commonly used clinical methods[1], thus MRI can be an important tool in the early detection of breast lesions and can provide an increased opportunity for minimally invasive therapies. A novel MR-compatible breast biopsy device for 3D access to the breast[2] was developed to improve interventional procedures for breast biopsy and cryoablation therapy[3]. This device has 6 degrees of freedoms. Its movement and the probe insertion are controlled remotely while the device and patient are in the scanner bore avoiding the need to pull the patient and device out of the scanner bore to perform the intervention and the ability to monitor the needle insertion process in real time. The existing MRI breast coils have several limitations for breast interventions. First they have limited space to accommodate the device. Second, the supporting structure often limits the movement needed access all breast regions. To accommodate the competing needs for high signal-to-noise performance of the breast imaging coil and open access to the breast tissue for intervention, the new breast coil was incorporated as an integral part of the interventional device. Moreover, the new coil design allows different coil sizes to be interchanged to accommodate different breast sizes.

Material and Method:

The new coil is based on a tapered solenoid design to provide close coupling of the RF-coil with the breast tissue as well as rotational symmetry as the device is rotated for lateral or medial interventions. By removing the close integration of the RF-coil electronics from the table support, it is possible to optimize both to improve access in the chest wall and medial regions without limiting the lateral access of conventional MR biopsy devices. The coil base, a parabolic shaped cup, is manufactured using a 3D printing process (Graphics System, Menomonee Fall, WI) directly from a Solidworks design model. The solenoid consists of 3 turns of copper conductors built around the cup frame with wide spaces between turns. There is a window on the structure positioned between the conductors designed for the biopsy/therapy probe to access the breast tissue. The cup also acts as a support for the breast immobilization system. Three sizes (large, medium and small) are available for the device roughly bracketing A-C cup breast sizes. The coil tuning networks are located on the base. Figure 1 shows the coil installed on the device.

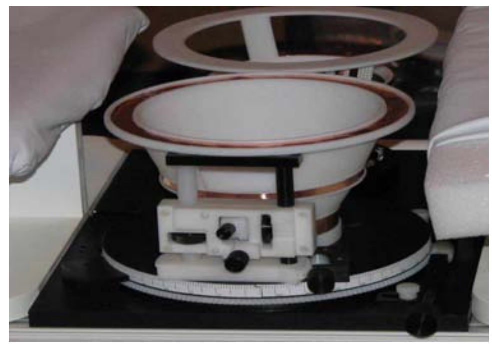

Figure 1. The solenoid coil installed on the biopsy/therapy device. 3 turns of copper is laid on the supporting structure (parabolic shaped plastic cup). Tuning networks are integrated.

The performance of the coil was tested by comparing signal-to-noise ratio (SNR) for the new coil relative to a commercial 7-channel (In Vivo/Medical Advances, Waukesha, WI) and 4-channel breast coils (MRI devices Corp., Waukesha, WI) used routinely for clinical breast MRI, including MRI-guided biopsy procedures. An SPGR pulse sequence (TR/TE 11ms/4ms Flip Angle 5 degrees, Band width ±31.25Mhz) commonly used for planning biopsy procedures was used on a 1.5T scanner (GE EXCITE II Echo-speed, Waukesha, WI) using spherical homogeneous phantom filled with copper-sulfate solution. Three regions in image are selected for measurement, upper, middle and lower in an axial image roughly corresponding to chest wall, middle and nipple in the breast. A gel breast phantom (Gammex Inc., Middleton, WI) is also used for comparisons. A healthy volunteer was also positioned in the device and routine breast imaging sequences was used to test patient comfort and coil performance in the clinical setting.

Region	SNR		
	Solenoid	7 Ch	4Ch
upper	9.6	8.9	11.9
middle	21.9	10.0	13.0
lower	54.1	10.4	16.0

Table 1. SNR comparison (homogenous phantom).

Result and Discussion:

The SNR comparisons are shown in table 1. Depending on position along the axis of the solenoid coil, the SNR is comparable or superior to the commercial coils tested, especially in lower region where the solenoid coil has a smaller conductor ring. The comparison images are shown in figure 2. The bright spots in image are near the position of the conductors. Qualitatively, images of the breast phantom image look sharper than those acquired with the commercial 4 channel breast coil used in our initial prototype for this device. In addition, the image quality is not affected by rotating the coil. This is important for our device since the coil will be rotated to optimize the location for needle/probe insertion for interventional procedures.

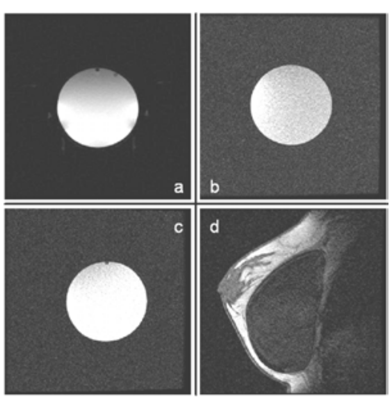

Figure 2. Comparison of developed solenoid coil (a) with traditional 7-channel (b) and 4-channel (c) coils with spherical phantom. (d) Slice of T1-weighted SPGR of human volunteer (with breast implants) using the solenoid coil.

Given the rotational symmetry, parabolic shape and ease of interchange to accommodate breast size, the coil is a very promising design for MR Image Guided Intervention applications. Note that the coil can also be used in general breast imaging for improved SNR. In future work, a decoupling network will also be integrated on the structure, allowing operation in the receive only mode. The coil design and device can also be used in 3T scanner (with different coil tuning), where higher resolution is readily achievable.

Reference:

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